Recording apparatus and method for optimized overwriting

The present invention relates to a recording apparatus and a corresponding method for recording information in an information layer of a record carrier, said information layer having a phase reversibly changeable between a crystalline phase and an amorphous phase.

In optical recording systems, such as recordable CD, DVD and BD systems, optimization of the write parameters such as write strategy, write power and erase power for each medium and for each write speed is very important. In phase-change rewritable systems, such as CD-RW, it has been observed that the properties of the previously written signal can also significantly influence the overwritten signal quality. Compatibility tests, e.g. test HS-ICOW (Inter Company OverWrite) carried out in CDs21 Solutions TWG2 (http://www.cds21solutions.org), have been carried out where High Speed CD-RW media are initially written by one drive and overwritten by another drive. The results included some poor performing writer/overwriter combinations. Possible causes for this poor performance are differences in write spot parameters as well as differences in write parameters, in particular write power, write speed, erase power and/or write strategy, of the two recorders.

During the development of the standard for Ultra Speed CD-RW (Recordable Compact Disc Systems, Orange Book part III: CD-RW, vol. 3: Ultra Speed v 1.0 and v1.1) a strong relation with write spot shape (e.g. oriented radially or diagonally with respect to the track) was observed: signals that are written with a radially oriented spot tend to be more difficult to overwrite. It is therefore expected that Ultra Speed CD-RW media will be more sensitive to incompatibilities that have been tested for High Speed CD-RW media.

It was noticed that signals that appeared more difficult to overwrite showed a rather high modulation. Indeed, the erasability (the remaining carrier signal after a DC erase) shows a strong dependency on the modulation of the previously written signal.

US 5,541,900 discloses an optical information recording and reproducing apparatus and method for different spot size type media. It includes a spot size recognizing circuit for recognizing a spot size suitable for an information recording medium to be loaded

and performs erasing, recording and reproducing to the information recording medium by defocusing or by off-tracking based on the spot size recognized by the spot size recognizing circuit. Therein a spot size suitable for the loaded information recording medium is recognized from the type of tab switch attached to the cartridge of the information recording medium or the management information recorded on the control track of the information recording medium. Based on the recognized spot size either a defocus amount is calculated indicating a difference between a recording face of the information recording medium and a focal point of the recording beam or an off-track amount is calculated indicating a difference between the center of a track formed on the recording face of the information recording medium and the focal point of the recording beam. This solution however needs a separate erase cycle in order to carry out above mentioned corrective actions (defocus or off-track). Therefore, it cannot be implemented on Direct OverWrite (DOW) based systems such as CD-RW, DVD±RW and BD-RE.

It is an object of the present invention to provide a solution for a recording apparatus and method solving the above described incompatibility problem which is also applicable for DOW based systems.

This object is achieved according to the present invention by a recording apparatus as claimed in claim 1, and a corresponding recording method as claimed in claim 11. Preferred embodiments of the invention are defined in the dependent claims.

The invention is based on the recognition that there is an interaction between the characteristics of the previously written signal and the optimum over-write conditions. It has been found that the key factor is the mark width of previously written marks. A radially oriented spot at high write power tends to write wide marks. If the overwriting spot has relative low power, possibly a smaller spot and a higher write speed, it will be difficult to completely erase such wide marks. These phenomena become even more critical with higher crystallization speeds. It is thus the general idea of the present invention to analyze the properties of the previously written signal by the overwriting writer and to use the results of this analysis by said writer to optimize the overwrite conditions in order to minimize the jitter.

In particular, it is proposed by the present invention to detect before and/or during overwriting if there are previously written marks and to determine the mark width of said previously written marks. Based on the result of this detection and determination the

write parameters are adapted such that previously written marks, irrespective of their widths, are completely erased with high certainty.

Preferred embodiments of the recording apparatus defining the control unit in more detail are defined in claims 2 to 4. One way for the recording apparatus to deal with wide previously written marks is to reduce the write speed. Where crystallization speed is critical, lower write speed (i.e. lower erase speed) will give more time to completely erase the wide previously written mark. Another way to optimize the overwrite process in case of wide previously written marks is to increase the erase power level. Thus, a wider area on the medium will be heated to above the glass temperature and complete erasure of the wide mark will be more likely. Alternatively, the write power level and/or the write strategy may be optimized.

The reduction of the write speed and/or the increase of the erase power level can be controlled dependent on the mark width of a detected previously written mark, preferably such that, for instance, the erase power level continuously increases and/or the write speed continuously decreases with increasing mark width. Alternatively, the reduction of the write speed and/or the increase of the erase power level can be made in steps depending on different levels or thresholds of detected mark widths. Preferably, the write speed and/or the erase power level are controlled such that a previously written mark is completely erased, irrespective of the width of the mark.

Preferred embodiments of the detection unit are defined in claims 5 to 7. One way for the recording apparatus to analyze the previously written signal is to measure the HF-modulation which can be seen as a measure of the mark width. From a threshold power level onwards, modulation increases monotonously with write power and finally saturates. The read-out spot will in general be bigger than the written mark. Hence, the ratio of amorphous and crystalline material is increasing with increasing mark width and modulation will saturate when the mark width reaches the limits of the effective spot on the information layer. Thus, also from the measured HF modulation the mark width of previously written marks can be determined.

Another way is to measure the HF crosstalk by a signal measurement between the written tracks. Since with increasing mark width and modulation in the written tracks the amount of signal detected when tracking on land increases, determination of the mark width is thus possible by measurement of the HF crosstalk.

Still another way is to measure the previously written signal strength during the actual erase procedure, which may be a way to monitor the previous mark width in real

time. The easiest method for mark width detection is the modulation measurement method because no land-groove switching and no high speed sampling during writing are required.

The invention will now be explained in more detail with reference to the drawings in which:

Fig. 1 shows different types of spot shapes of a radiation beam used for writing marks,

Fig. 2 shows different mark widths written by a radiation beam having a spot shape shown in Fig. 1,

Fig. 3 shows a block diagram of a recording apparatus according to the present invention,

Figs. 4a, 4b and 4c show a data signal and control signals according to the invention for controlling the power level of the radiation beam during recording, and

Fig. 5 shows a flow chart of a start-up write sequence with write speed optimization based on the previously written signal characteristics.

Fig. 1 shows different spot shapes of recording beams used for recording marks in the information layer of an optical record carrier of the phase-change type along the track Tr oriented along the tangential direction t and perpendicular to the radial direction r of an optical record carrier. A radially oriented spot S1 having the shape of an ellipse with its long axis perpendicular to the tangential direction t, a diagonally oriented spot S2 having its long axis 45 degrees with respect to the tangential direction t and a tangentially oriented spot S3 having its long axis parallel to the tangential direction t are shown. The shapes of recorded marks M1, M2, M3 (having a length of 4T) written by a radiation beam having such different types of spot shapes are shown in Fig. 2.

Fig. 3 shows an embodiment of the recording device according to the present invention for recording marks in an information layer 101 of a disc-shaped record carrier 10. The information layer 101 is of the so-called phase-change type, that is, it has a phase reversibly changeable between a crystal phase and an amorphous phase. The record carrier is rotated around its center by a motor 14. A radiation beam 12 is generated by a radiation source 11, such as for example a laser light source, and focused onto the information layer 101 by a lens 13.

The power of the radiation beam 12 is controlled by a control signal S_C provided by a control unit 15, where it is assumed that the power of the radiation beam 12 is proportional to the corresponding level of the control signal S_C. Examples of such a control signal S_C are shown in Figs. 4b and 4c. The control unit 15 converts a digital data signal S_D representing the length of a mark to be recorded in the information layer 101 of the record carrier 10 into a corresponding control signal S_C. This conversion is based on a so-called write strategy. An examples of such a digital data signals S_D is also shown in Fig. 4a.

The patterns of the pulses and the gaps between the pulses in a control signal S_C are controlled by the control unit 15 based on mark width information W determined by the detection unit 16. Additionally, the motor control signal S_M, setting the rotational motor speed is also controlled by the control unit 15 based on mark width information W determined by the detection unit 16. The detection unit 16 detects if there are previously written marks present in the track of the information layer in which new information shall be recorded. Further, if there are previously written marks present, then also the mark width of such previously written marks is detected.

In a preferred embodiment, the detection unit 16 is adapted for measuring the HF modulation, particularly in the DC coupled HF-signal as (A-B)/A with A the top level of a long (e.g. I11 in CD; I14 in DVD) space and B the bottom level of a long mark.

In another preferred embodiment, the detection unit 16 is adapted for measuring HF crosstalk between the written tracks. HF crosstalk is preferably measured as the ratio of HF signal amplitudes tracking on the land and in the groove of the information layer.

Fig. 5 shows a flow chart of a start up write sequence of the latter two embodiment where write speed is optimized based on the previously written modulation or crosstalk. This can be done each time a writing action is started.

In still a further embodiment shown in Fig. 3 the detection unit 16 is provided for (almost) real time measurement by making use of reflected light outcoupled by a beam splitter 17 during writing. This outcoupled signal R, modulated by the write pulse, includes information about the reflectivity state of the information layer before and during the overwriting process. Accurate and fast sampling of the reflected light is thus required to enable such a real time measurement of the signal amplitude during recording.

Based on the mark width information W the control unit 15 adapts the control signal S_C. In particular, the patterns of the pulses and the gaps between the pulses in the control signal S_C, the write speed and the power levels are set. Preferably, with the increasing

mark width the overwrite speed is reduced and/or the erase power level of erase pulses is increased in order to ensure that previously written marks are completely erased when new information is recorded.

An example of a digital data signal S_D to be recorded is shown in Fig. 4a. Examples of control signals S_C relating to the digital data signal S_D are shown in Figs. 4b and 4c. Fig. 4b shows a first control signal S_{C1} used when no marks or marks of "normal" width are previously recorded in the information layer, and Fig. 4c shows a second control signal S_{C2} used when wide marks are previously recorded in the information layer. The digital data signal S_D is shown as a function of time, the value of the signal representing information to be recorded. In the example the data signal S_D subsequently comprises a 3T space, a 4T mark, a 6T space and a 7T mark, T representing the period of a reference/data clock, also called the channel clock period.

The data is written in an optical rewritable record carrier having an information layer, which information layer has a phase reversibly changeable between a crystalline phase and an amorphous phase. The marks representing the data are written along a track in the information layer by irradiating it with a pulsed radiation beam in order to write the marks. Previously written marks representing the data are erased along a track in the information layer by irradiating it with a CW (Continuous Wave) radiation beam. In case of Direct OverWrite systems, during rewriting an erase level is applied in between write pulses to erase the previously written marks. The control signals shown in Figs. 4b and 4c use an N-1 write strategy, i.e. the number of write pulses for writing a mark having a time length of NT equals N-1, i.e. three write pulses 21 are applied for writing the 4T mark and six write pulses 22 are applied for writing the 7T mark, all write pulses having a constant write power level P_w. Previously written marks are erased during writing the spaces by applying constant erase levels 23, 24 P_{e1}.

In the second control signal S_{C2} used when there have been marks detected previously written and having a large width is shown. As can be seen, in this embodiment the erase power level P_{e2} of the erase pulses 33, 34 are increased compared to the power P_{e1} of the first control signal S_{C1}. At the same time, the writing speed may be reduced, such that the clock period T is increased. Thus, it can be ensured that the previously written marks are completely erased.

The present invention is not limited to the embodiments shown in the figures and described above. Particularly, other write strategies (e.g. 2T type write strategies) can be applied as well, e.g. the use of a pulsed radiation beam is not necessarily required. Further,

there are different ways of evaluating measured mark widths and of optimizing the write strategy which shall all be covered by the present invention.

Last, although the invention has been explained with reference to optical disks, the invention could be applied to other types of information carriers, like for example magneto-optical disks.